6-4 Outline and Problem of Reclaimed Water Supply Business in Tokyo

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ABSTRACT
Tokyo Bureau of Sewerage (TBS) of Tokyo Metropolitan Government (TMG) is proceeding to the advanced treatment and recycling the treated wastewater for various uses in urban areas.
Results of the amount of the reclaimed water supply in 2007 were 30,635,400m3/year. This corresponds to 1.9% of the amount of the authorities total discharged water.
In the main usage, flush toilet water was 3,261,900m3/year, and discharge for a river basin environmental recovery to the river where the flow of the river had decreased was 27,329,400m3/year. Besides this, it is used to the road watering for mitigation of the heat island phenomenon, and sprinkling the plant, etc.
This business has the problem concerning the supply volume of water, the water quality, crisis control.
The problem of the supply volume of water is shortage of make water ability at the peak of use. We cope with this problem by a fine operation management and by the reinforcing ability of make water.
The problem of the water quality is a disappearance of the residual chlorine, the incorporation of the chironomidae larvae, and the establishment of the risk management technique to a pathogenic chlorine resistant microorganism. The countermeasure concerning chlorine is to improve the nitrification efficiency on the sewage treatment process. Pathogenic microorganisms and chironomid countermeasures is the installation of equipments that can remove them and of the disinfections by ozone and ultraviolet rays.
Deterioration of piping and partition valve and the risk management at the earthquake are problem on the facilities side, it is necessary to settle on short-term and a long-term facilities planning, and to execute it steadily.

KEYWORDS: reclaimed water, residual chlorine, chironomid, ceramic filtration

INTRODUCTION

The water consumed in Tokyo is conveyed from distant sources which are not necessarily capable of providing sufficient amount of water every year.
Now that the stable water supply is conceived to be even threatened by the climate change of

global scale, the risk of water scarcity is the critical challenge of Tokyo Metropolitan Government (TMG). Thus, TMG addresses not only the development of new water resources but also the reuse of wastewater and harvested rainwater. Actually, citizens are getting aware that the municipal effluent could be a new water source in Tokyo.

TBS of TMG is proceeding to the advanced treatment and recycling the treated wastewater for various uses in urban areas. In this paper, I report the outline of a reclaimed water supply business, and a problem, and its countermeasure.

1. Guideline for water reclamation and reuse businesses

TBS established the guideline for water reclamation and reuse businesses. The contents are as follows.

1.1 Water supply area

The supply areas are the following seven areas.

①Nishi Shinjuku and Nakano Sakaue area, ②Tokyo Waterfront City area, ③Shinagawa Station east entrance area, ④Osaki area, ⑤Shiodome area, ⑥Nagatacho and Kasumigaseki area, ⑦Yashio and Higashi Shinagawa area

1.2 Water supply object

Building that has the total floor space of over 10,000 m^2 or the amount of wastewater over 50m^3/day (except housing part).

1.3 Supplied water quality and supply hydraulic pressure

The standard of the supply water quality and supply hydraulic pressure is Table 1.

Table1. Standard of the reclaimed water supply

ITEM	STANDARDS
E.coli	Not detect
pH	5.8 ～ 8.6
Residual chlorine	Maintain
Odor	Not discomfort
Appearance	Not discomfort
Hydraulic pressure	More than 0.05MPa

1.4 Charge

The charge of the reclaimed water is 260 yen/m^3. The basic rate system is not employed. In addition, the charge is not calculated to rise by increasing the consumption.

1.5 Facility criterion

Pursuant to the standard of customer's facilities, the receiving water tank should be set up without fail, and misconnection to the potable water supply system is strictly prohibited.

2. Outline of reclaimed water supply business

2.1 Water reclamation process

The reclaimed water is produced in three water reclamation centers; Ochiai, Ariake, and Shibaura. As shown in Table 2, the three reclamation centers adopt different types of treatment processes.

In the Shibaura Water Reclamation Center, which mainly supply good quality water processed by ozone and microfiltration. In the time when demand increases greatly, the sand filtration

Table 2. The processing system of a water manufacture institution

Water reclaimed center	processing system
Ochiai	Secondary effluent → Sand filtration → Chlorine disinfection → Water supply
Ariake	Secondary effluent → Biological filtration → Ozonation → Chlorine disinfection → Fiber filtration → Water supply
Shibaura	Secondary effluent → Biological filtration → Ozonation → Microfiltration → Chlorine disinfection → Water supply ↑ Secondary effluent t→ Sand filtration → Fiber filtration

(fiber filtration) water is added to the microfiltration water to make up for the lack of the make water ability. The blend rate makes 50% the upper limit to restrain a rise of the chromaticity.

The main reason why the treatment process is different at each center is that the water quality of the second effluent is different and the annual that constructs facilities is different.

It is scheduled to change to the method to process the whole water by biofilm filtration → ozonization → microfiltration one by one to assume a hygienics risk to be the minimum one and to expand the usage in the future.

Here, the fiber filtration device is filter with the screen of fiber material and 30μm of meshes of a net. And the high-speed processing that filtration speed is 1,000m/ day is possible. This device was introduced for removal of the egg of a chironomid, and of a larva.

2.2 Usage

The main usage of the reclaimed water is the rest room washing water, and, besides this, is used for watering planting, the rinse water of the railroad vehicle, and the road sprinkling as countermeasures for the heat island.

Although it is outside the range of this business, it has been contributing to the creation of the waterside space by supplying the reclaimed water at the Ochiai water reclaimed center to the river that dries up.

2.3 Supply results

The reclaimed water supply business was begun as a model business. That supplied the sand filtration water at the Ochiai water reclaimed center to the building of the Nishi Shinjuku area in six places in October, 1984.

Table 3 shows the supply results in 2007. Transition of the past number of institutions is shown in Fig. 1.

On the other hand, the amount of the water supply has increased as the number of supply facilities increases. The entire results in fiscal year 2007 were 3 million 258 thousand m3 during year. Figure 2 shows the transition of the amount of the water supply from beginning of water supply.

In the area that has been supplied since as early as the Nishi Shinjuku area, there is no too

Table3. Outline of reclaimed water supply business

Water Reclaimed Center	Name of Supply area	Supply beginning	Supply area (ha)	Supply number	Water supply Results (m^3)
Ochiai	Nishi Shinjuku and Nakanosakaue	1984.10 1996.03	80	29	1,171,472
Ariake	Tokyo Waterfront City area	1996.02	681	74	775,013
Shibaura	Shinagawa Station east entrance	1997.10	83	19	645,168
	Osaki	1998.11	67	7	163,366
	Shiodome	2002.11	31	16	417,385
	Nagatacho and Kasumigaseki	2007.10	138	3	37,982

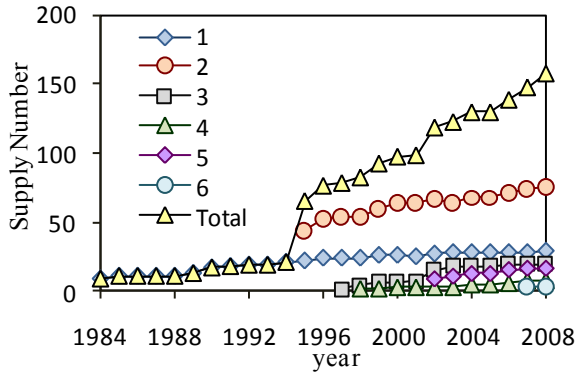

Figure1. Transition of number of reclaimed water supply facilities

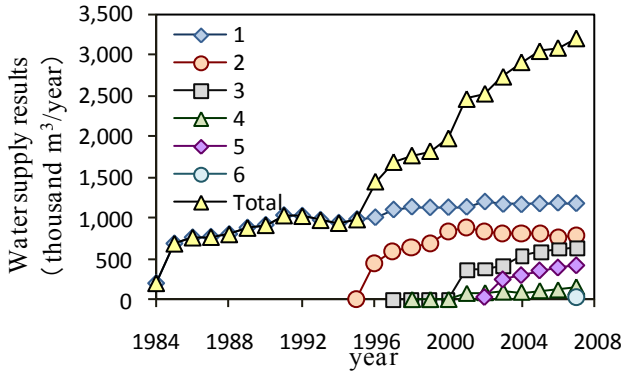

Figure2. Transition of amount of reclaimed water supply

big expansion. On the other hand, since it is carried out by construction of a building continuing, a pace of expansion is high in areas, such as the Osaki area and the Shiodome area, while redevelopment is advancing.

2.4 Supply water quality

The water quality of the supply water in the 2007 fiscal year is shown in Table 4.

Every item was within the limits of the "technical standard of the reuse water quality of sewage disposal water" which the Ministry of Land, Infrastructure and Transport defined.

Table4. Reclaimed water quality in 2007

		Shibaura		Ariake		Ochiai		Standard in technology
		average	range	average	range	average	range	
pH		7.0	6.7-7.3	7.4	7.3-7.6	6.7	6.5-6.9	5.8-8.6
Free residual chlorine	mg/L	1.5	0.13-4.1	0.31	0.18-0.58	0.70	0.15-2.0	0.1mg/L or less
Combined residual chlorine	mg/L	1.2	0.07-2.6	0.54	0.30-0.76	0.63	0.21-2.1	0.4mg/L or less
Chromaticity	deg	3	1-5	3	2-4	3	3-8	10deg or less
Turbidity	deg	0.4	0.1-0.7	0.4	0.1-0.9	0.4	0.2-0.9	2deg or less
E.coli	-	N.D.	-	N.D.	-	N.D.	-	Not Detect
Chlorine ion	mg/L	174	66-291	161	47-211	57	45-70	
TOC	mg/L	5	3-6.8	5.8	5.2-7.4	4.3	3.3-4.9	
Phosphate ion	mg/L	1.5	0.37-3.6	0.48	0.24-0.6	4.1	2.8-4.9	
Total solids	mg/L	556	270-790	550	470-640	282	220-330	

3. Problem and countermeasure of reclaimed water supply business industry

It has the problem concerning the volume of water, the water quality, and facilities, and an appropriate action is needed for a further supply expansion.

3.1 Supply volume of water

Problem

The main usage of the reclaimed water is the flush toilet water, so the use peak overlaps everywhere. Therefore, the processing performance might be temporarily exceeded, and the facilities ability should be made proper for the stable supply.

Countermeasure

This phenomenon occurs in Shibaura Water Reclamation Center. So, the microfiltration facilities are scheduled to be constructed in the Shibaura Water Reclamation Center by March, 2010. As a result, the make water ability of ozone + microfiltration facilities is improved from 3,000 to 9,000m3/day. After facilities are completed, the blend rate of the sand filtered water to microfiltered water is scheduled to be lowered to 10% or less.

3.2 water quality

3.2.1 residual chlorine

Problem

As for the water for miscellaneous use of the building, observance of residual chlorine standard value is obligated in the law. Therefore, disappearance of residual chlorine is great concern for the building user who is the customer and there are a lot of complaints, too.

To calculate the designed value of the amount of water used excessively in a lot of buildings, the water receiving tank becomes excessive. Therefore, the retention time of the water receiving tank becomes long, and the residual chlorine disappears in the meantime.

The disappearance speed of the residual chlorine depends on the water quality of the reclaimed water. Therefore, the concentration of the residual chlorine of the supplied reclaimed water changes greatly with 0.1-3.0mg/L. The concentration control of residual chlorine in the customer facilities is very difficult.

Countermeasure

The reclaimed water contains a lot of materials that react with the residual chlorine such as ammonia nitrogen and the organism, compared with tap water.

As for the residual chlorine, the concentration control is very difficult; following countermeasures for stabilization of residual chlorine are examined.

- Ammonia nitrogen exerts the most influences on the disappearance of the residual chlorine. Operation of accelerating the nitrification is executed for reducing ammonia nitrogen.
- Chlorine inject before service reservoir. Chlorine reacts with the chlorine consumption material in the service reservoir; as a result the chlorine consumption material in reclaimed water decreases. The concentration of the residual chlorine in reclaimed water is steady by the additional chlorine injection at the time of the water supply.

- Because ozonization oxidizes and resolves the organic compound that is the chlorine consumption material, it is effective for the stabilization of the concentration of the residual chlorine.
- At the consultation before contracts, consult in detail with customer about the size of receiving tank and the chlorine injection equipment.

3.2.2 Chironomid

Problem

The chironomid lives in the sand layer of the sand filtration and the biofilm filtration. Because chironomidae egg easily goes through the sand layer, the possibility that the chironomid mixes into filtered water is high. The egg in the supplied reclaimed water hatched in the receiving tank, and there was a case where the larva was seen in the toilet in customer's building. The chironomid causes the lowering reputation of the building and it leads to the reduction of the reclaimed water use.

Countermeasure

There are two kinds of measures.

The first measure is a method of filtering by the filter media of the small diameter, and removing the egg and the larva physically. The example is the fiber filter device introduced into both the water reclamation center in Ariake and Shibaura.

The second measure is addition of a medicine. The medicine used is disinfectant such as chlorine and ozone, or is pesticide that annihilates a chironomid directly. As for a medicinal effect, the direction of pesticide excels. However, probably, it will be better to use an antiseptic, if safety is taken into consideration. Furthermore, an antiseptic is contributed also to stabilization of residual chlorine.

3.2.3 Hygienic risk management

Problem

There is possibility of pathogenic microbe mixing of the human waste origin in the water which blended sand filtration water and sand filtration water. Since reclaimed water is chlorinating, many bacteria have become extinct. However, chlorine disinfection is not effective to some of viruses (Norovirus etc.) or protozoans (Cryptosporidium etc.) which are pathogenic microbes. Hygienic risk management including those measures is important.

Countermeasure

Norovirus was detected to sand filtration water and biofilm filtration water in several times investigation by the PCR methods. Since the number of times of investigation is a little, the significance of results cannot determine. We conduct detailed investigation, in order to grasp the actual condition.

TBS is planning to perform whole-quantity ozonization + microfiltration treatment in order to prevent mixing of the pathogenic microbe and hazardous chemicals to reclaimed water.

3.3 Deterioration of piping

Deterioration of piping and partition valve and the risk management at the earthquake are

problem on the facilities side, it is necessary to settle on short-term and a long-term facilities planning, and to execute it steadily. TBS decides upon and carries out the repair plan of piping.

4. New technologies in reclaimed water manufacturing

The combining system of ozonation and micro filtration was installed and operated in Shibaura Water Reclamation Center to cope with the problems of water quality such as color, odor, pathogens etc (since 2004).

The present microfiltration is using the hollow fiber membrane of high crystallinity polyvinylidene fluoride (PVDF) with ozone tolerance. In the Shibaura water reclamation center, since water quality is not good, the injection rate of ozone has been set up highly. For this reason, the life of the hollow fiber membrane became short sharply, so the cost of making water was rising.

Then, we did research on making of reclaimed water by ceramic filtration. This new system produces reclaimed water in Shibaura water reclamation center (Treatment capacity is 4,300 m^3/day). Durability against ozonation is improved, compared with ordinal polymer membrane.

We are developing new system to make micro filtration cheaper and more durable. Durability improvement and cost reduction will be realized by use of Ceramic membrane. The features of the ceramic membrane system are as follows;

① There is neither chemical deterioration nor changing in performance against heat and pressure, and everlasting endurance is expected.

② It excels in heatproof and corrosion resistance, and there are no elutions of impurities.

③ Mechanical strength is high, and there is no film damage.

④ It excels in chemical resistance, and the recovery of the film performance by the medicine washing is easy.

⑤ As for a used film, the material recycle is possible as the ceramic raw material

There is an advantage.

The photograph of the ceramic module is shown in Figure 3 and the construction drawing of the ceramic module is shown in Figure 4.

Figure3. Ceramic module (The outer diameter of 180mm, and 1,500mm in length)

Processing consists of biological filtration, oxidation by ozone, coagulation and microfiltration.
In the water manufacturing facility at the Shibaura water reclaimed center that operates in 2010, the ceramic membrane is supposed to be used for microfiltration.

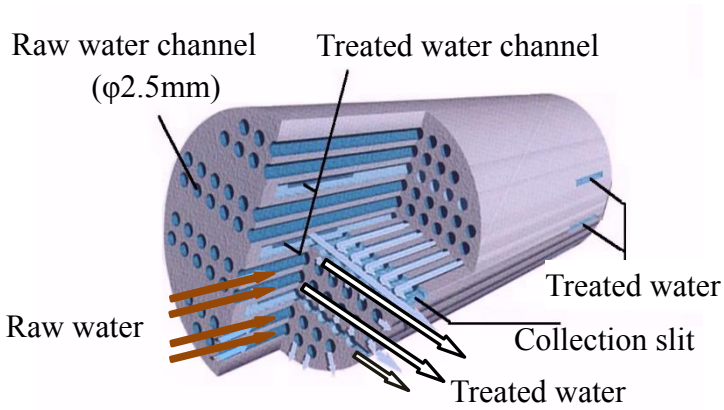

Figure4, Structure of ceramic membrane module

5. Future Directivity

In the ward area of Tokyo, the sewer of 4,806,000m^3 per day has treated, and it has discharged to the public water. On the other hand, quantity of total reclaimed water was 86,098m^3, it is only about 2% of discharged water. It is necessary to make an effort for a further supply in the future.

For increase of the amount of the supplied water, it is necessary to find out a new use. We will carefully review the hygienic risk of reclaimed water, to find new uses such as cooling tower water in the building.

Concentration of the chloride ion of the reclaimed water is high, so the pitting corrosion in stainless piping is feared. Therefore, in the principle TBS prohibits using the stainless steel to piping of the reclaimed water. We will investigate the relation between chloride ion concentration and piping corrosion, and grasp the concentration which does not cause piping corrosion. As a result, it becomes possible to supply also to buildings other than new building, and the demand for the reclaimed water will rise.